

CHAPTER 6

THE TEST

CHAPTER OBJECTIVES

Upon completion of this chapter, you should be able to:

1. Describe the pre-test determinations set forth in the EPO's for gravity-discharge and power-operated vehicle-tank meters,
2. Understand the purpose of each of the separate tests prescribed in the EPO's and the significance of the results obtained.
3. Describe procedures for conducting performance tests of gravity-discharge and power-operated vehicle-tank meters.

INTRODUCTION

A measuring device that conforms with all of the specific requirements relating to design, installation, maintenance, and use set forth in Handbook 44 may still not be capable of the high degree of accuracy and consistency of measurement demanded for commercial service. Thorough inspection may give you some indication of the condition of the vehicle-tank metering system you are examining, but this impression will be based upon evidence that is limited by the fact that the system is not in its operating state, and so it may even be misleading. For example, a metering system that is clean and, to all outward appearances, well maintained, may be badly worn or in need of calibration. The only way to determine for certain how the system is likely to perform is to test it under conditions that approximate as closely as possible actual service conditions. This is the purpose of the Test portion of an official examination.

In fact, the Test is comprised of several separate tests, each of which has a specific testing objective. Some of these tests are intended to determine the accuracy of the system over the range of operating conditions for which it was designed (and, presumably, is used). Others are intended to test specific elements of the system, like the air eliminator or the antidrain valve and others are designed to verify that the system is being properly maintained. You should understand not only how to perform each of these tests, but also the reasons for performing them, and how to make use of the results you obtain.

For example, you will learn in this chapter that the EPO's call for tests of the system at different discharge rates. Let us consider the reasons for this requirement. Figure 6-1 shows a typical "accuracy curve" for a vehicle-tank meter. The graph represents the performance of the system over the range of flow rates for which it was designed. However, the word "performance" must be qualified here. Meter manufacturers publish accuracy curves like this one to advertise their equipment, because they illustrate graphically the high degree of accuracy of which most positive-displacement meters are capable. Accuracy curves produced by manufacturers are generally the result of tests conducted on new equipment in a laboratory or under very controlled conditions. They therefore can not be considered to provide anything more than

a very general indication of how the equipment will actually perform when installed and operated in the field (they are in this way very much like the mileage estimates publicized by automobile manufacturers, useful for comparative purposes only).

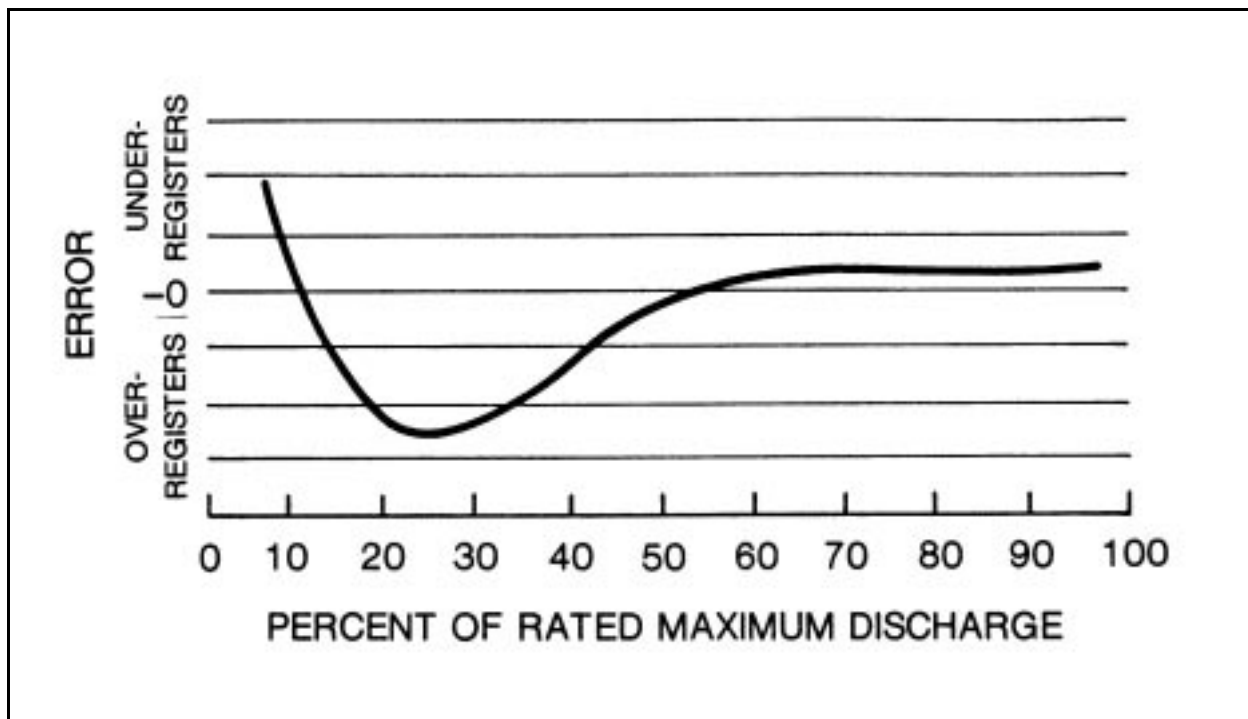


Figure 6-1. Accuracy Curve I

This graph does, however, illustrate several important general characteristics of meter performance. Notice that at very low discharge rates -- up to about 10 percent of the recommended maximum rate -- this typical system tends to "give" slightly more than at its maximum discharge rate. That is, it tends to deliver slightly more product per indicated gallon. At discharge rates between 10 percent and about 50 percent of the rated maximum, the system tends to "take" slightly -- deliver slightly less product per indicated gallon -- than at its maximum rate.

We use the terms "give" and "take" to describe these fluctuations rather than "underregister" and "overregister" because registration is a function of the system's calibration and not necessarily its performance. Power-operated vehicle-tank metering systems are operated at or near their maximum discharge rates most of the time, and gravity-discharge systems generally deliver at rates above 50 percent of their rated maximum, even at low head. So most systems are calibrated to indicate as accurately as possible at their maximum discharge rates. However, a system could be adjusted (or misadjusted) to perform as described by the curve shown in Figure 6-2, underregistering at all discharge rates, though least between about 20 percent and about 30 percent of its maximum rate. Notice that the shape of the curve has not changed, nor have the relative performance characteristics described by the terms "give" and "take": the system still gives slightly more at very low discharge rates and takes slightly more at moderate rates than at its maximum discharge rate.

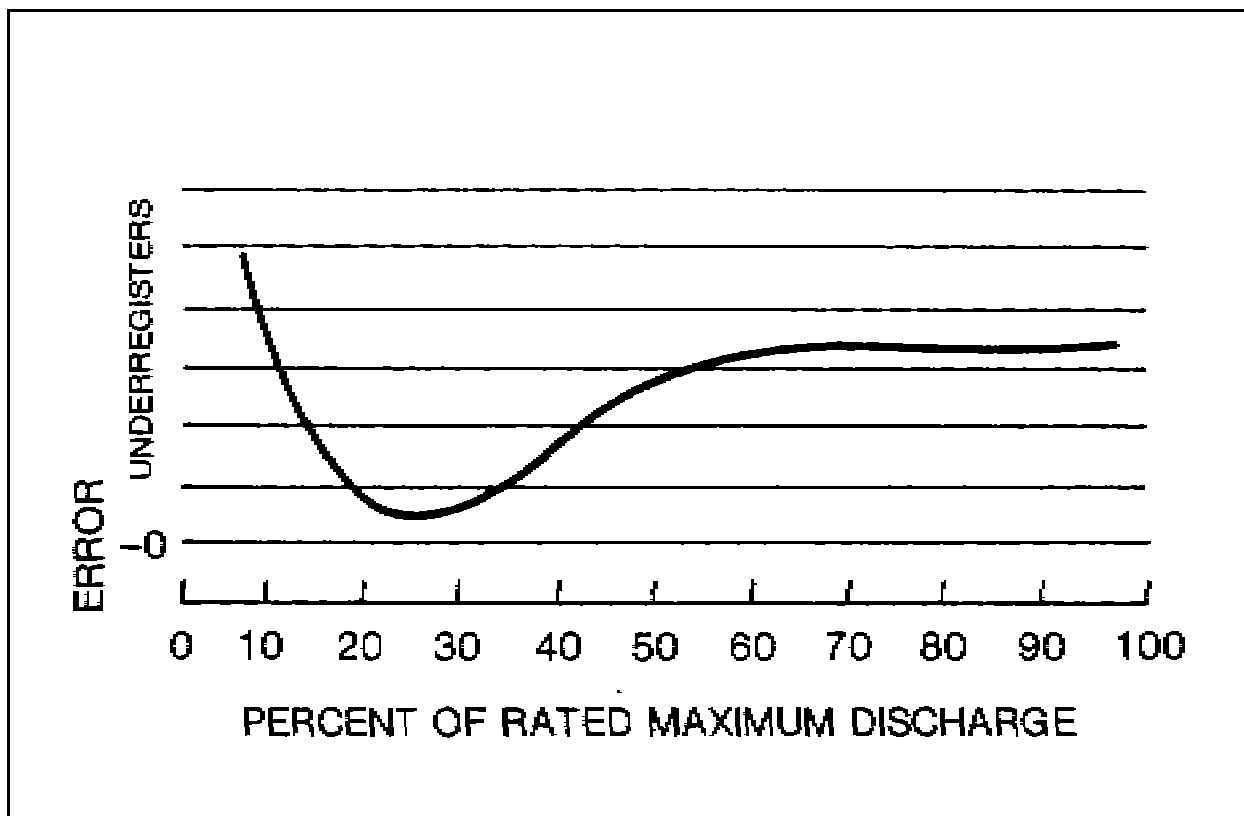


Figure 6-2. Accuracy Curve II

You can see from this discussion one reason why it is necessary to test a metering system at different delivery rates: even a system that is properly installed, maintained, and operated can be expected to perform differently at different discharge rates. Furthermore, as the example in Figure 6-2 shows, a system that performs reasonably accurately at one rate may be inaccurate when operated at other rates.

The fluctuations in performance over the range of a system's discharge rates result from several factors, but the most important of these is variation in the rate of slippage. Minute quantities of product slip continuously through the small clearances between the segmenting elements of the meter and the polished walls of the meter chamber whenever the system is operating. The rate of this slippage is, in large part, a function of the friction produced between the molecules of the flowing liquid and those of the metal surfaces with which they come in contact. The amount of this friction is different at different flow rates. The amount of slippage and mechanical friction in the meter also depends upon the characteristics of the product being measured. Consequently, meters must be tested and adjusted using the product to be metered or a liquid having similar characteristics.

The hydrodynamic and mechanical principles that underlie these flow characteristics are complex, and need not concern us here. However, keep in mind that slippage is the primary factor in the fluctuations in meter performance we have discussed, because this also relates to the second reason for testing meters at different discharge rates -- to determine the condition of the meter.

The performance curve shown in Figure 6-1 is typical of a relatively new meter. As a meter wears, its clearances gradually widen, with the result that the rate of slippage increases and the shape of the curve

itself is eventually altered. A badly worn meter will tend to give more not only at very low discharge rates, but also at moderate rates, than at its maximum rate. Thus, the actual performance of a meter tested at different discharge rates can give an indication of its condition and can thereby provide information that is useful to the operator and repairpersons in determining what corrective action is needed to restore the system to an accurate condition. A meter that is not badly worn may simply require readjustment, which will have the general effect of raising or lowering the entire performance curve. On the other hand, a badly worn meter will probably need reconditioning, the effect of which will be generally to restore the characteristic performance of the meter to a condition similar to that when it was new. We will take a closer look at the interpretation of results from performance tests at different discharge rates later in this chapter.

As you have learned, the accuracy of a vehicle-tank metering system depends upon a number of components whose functions are interdependent. For example, failure of the air eliminator to remove air and vapor from the product before it enters the meter will result in some degree of overregistration, since gases will be metered along with the liquid product. But under "normal" operating conditions malfunction of the air eliminator may be difficult to identify and isolate from other factors, or it may be offset by some other factor that tends towards underregistration, such as improper calibration. However, under the demands that arise when the tank or tank compartment is emptied during the course of a delivery, the failure of the air eliminator is likely to have a much more pronounced effect on performance. A separate test of the system under these special conditions is thus needed to determine whether it is capable of performing accurately and also to identify (or preclude) the air eliminator as the source of overall system inaccuracy.

Differences in operating characteristics between gravity-discharge and power-operated systems necessitate some differences in test procedures. These will be described in detail below. However, the basic elements of the Test are the same for both types of system:

- Tests of system performance across the range of flow rates recommended by the manufacturer.
- A test of the air eliminator, involving a delivery that exhausts the supply of product in the tank or tank compartment.
- A test of the automatic-stop (preset) mechanism, if the system is equipped with one.
- For electronic systems, a test for susceptibility to radio-frequency and electromagnetic interference (RFI/EMI).
- Tests of indicating and recording elements for comparability of indications and, in the case of computing registers, correct computation of price.

In addition, the antidrain valve on power-operated systems is tested.

We will take a closer look at each of these tests, outlining the procedures -- which you will study and practice further during your field training -- and describing the interpretation of test results. However, before we do this, we must first discuss several important determinations that you must make before any testing begins.

PRE-TEST DETERMINATIONS

Four separate sets of pre-test determinations are prescribed in the EPO's for both gravity-discharge and power-operated systems as described below. A fifth set, required for gravity-discharge systems only, will also be described.

Pretest Determinations Section of EPO:

1. Determine that the test fluid in the tank compartment is similar in character to the fluid to be measured commercially.

All liquids have distinctive physical properties, such as viscosity, gravity, vapor pressure, coefficient of thermal expansion, etc. Because these properties are associated with factors that affect the performance of a system, the properties of the substance(s) that will be measured are taken into account in selecting the appropriate equipment, and in calibrating the system after it has been installed. In most field examinations, the tank will be filled with the product that it normally holds. In some cases, however -- especially when the commercial product is extremely toxic or volatile, and would present a potential hazard if used in testing -- a non-hazardous liquid may be used, provided that it has the same general characteristics as the commercial product.

N.1. Test Liquid.

- (a) A measuring system shall be tested with the liquid to be commercially measured or with a liquid of the same general physical characteristics. Following a satisfactory examination, the weights and measures official should attach a seal or tag indicating the product used during the test.
(Amended 1975)
 - (b) A milk measuring system shall be tested with the type of milk to be measured when the accuracy of the system is affected by the characteristics of milk (e.g., positive displacement meters).
(Amended 1989)
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It is generally the responsibility of the owner or operator to assure that the liquid used in the test is either the product that is normally dispensed, or an acceptable substitute. You should ask the operator to identify the fluid in the system at the beginning of the test and whether or not it is the commercial product normally delivered, and record the response on your official report form. You will not, of course, be able to test to verify this information in the field. If you have reason to believe that the identification provided by the operator is not accurate, or that a substitute test liquid does not have the proper general physical characteristics, you should request verification from the operator or, if necessary, request a sample to take with you for further testing.

2. Determine whether the prover size is adequate.

The nominal capacity of the prover used for the Test must be no less than the amount of product that can be delivered by the system in one minute at its maximum discharge rate. If, for example, you ascertain (from the required markings on the meter) that the maximum discharge rate recommended is 184 gpm, you would need a prover with a nominal capacity of at least 184 gal (in all probability, the standard available prover size that will be adequate will have a nominal capacity of 200 gal).

This test requirement, like that quoted above for the test liquid, is included in the Vehicle-Tank Meters Code as a Note.

N.3. Test Drafts. - Test drafts should be equal to at least the amount delivered by the device in one minute at its maximum discharge rate, and shall in no case be less than 180 L (50 gal) or 225 kg (500 lb).
(Amended 1989)

The reason for this requirement is that any positive-displacement meter will perform less accurately at the very beginning and end of a delivery, because some of the energy of the moving fluid, which should be transferred directly to the indicating elements, must be used to overcome inertia (the tendency of a body that is at rest to remain at rest and of a body that is in motion at a given speed, to remain in motion at that speed). Once the meter has attained a constant rate of revolution, called a "steady state," inertial resistance is virtually eliminated until the meter must decelerate to a stop at the end of the delivery. Because the inaccuracy resulting from inertial factors will be the same for all deliveries made under the same conditions (with the same liquid at the same rate) -- provided that the meter has reached a steady state -- the effect on the accuracy of any given indicated delivery will be a function of the quantity delivered: The larger the delivery, the smaller the effect as a percentage of the quantity delivered. The fact that a meter can be expected to attain and operate at a steady state within one minute, and the fact that deliveries of less than this amount are not usual for vehicle-tank systems, provide the bases for this general requirement, which effectively establishes a minimum delivery time for any test draft.

If a gravity-discharge system is being tested, you must also determine that the prover inlet is lower than the meter outlet. If it is not, delivery may be impossible or may be interrupted before the draft is finished.

3. Determine applicable tolerances.

It is recognized that neither the measuring device being tested nor the standard used to test it is capable of errorless value or performance under all sets of operating conditions that are obtained in the field. For this reason tolerances are established to fix the acceptable range of inaccuracy for devices in commercial use. Tolerances are intended to permit measurement errors that are small enough that they cannot cause serious economic injury to either buyer or seller. At the same time, however, tolerances must not be so stringent as to make the costs of manufacturing and maintaining commercial equipment unreasonably burdensome, since these costs are ultimately passed on to the consumer. The tolerances established by code or

regulation and enforced by weights and measures jurisdictions are considered as minimum requirements by manufacturers and industries; they can, and often do, establish performance standards that are more stringent.

The specific tolerance value that applies for a particular test of a particular vehicle-tank metering system is determined by three factors:

- The amount of time the device has been in service.
- The type of test that is being performed.
- The size of the test draft.

For vehicle-tank meters -- as for all mechanical devices whose errors in performance can be expected to increase as a result of extended use -- Handbook 44 sets forth two sets of tolerances:

G-T.1. Acceptance Tolerances. - Acceptance tolerances shall apply to:

- (a) equipment to be put into commercial use for the first time;
 - (b) equipment that has been placed in commercial service within the preceding 30 days and is being officially tested for the first time;
 - (c) equipment that has been returned to commercial service following official rejection for failure to conform to performance requirements and is being officially tested for the first time within 30 days after corrective service;
 - (d) equipment that is being officially tested for the first time within 30 days after major reconditioning or overhaul; and
 - (e) equipment undergoing type evaluation.
- (Amended 1989)

G-T.2. Maintenance Tolerances. - Maintenance tolerances shall apply to equipment in actual use, except as provided in G-T.1.

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- acceptance tolerances are applied to new equipment when it is first put into service, when it is returned to service after reconditioning or replacement of major components, or when adjustments or repairs have been made as the results of a weights and measures compliance action.
 - maintenance tolerances are applied to equipment that has been in service for more than 30 days.

The acceptance tolerance for a vehicle-tank meter is specified as one-half the value of the applicable maintenance tolerance. The maintenance tolerance therefore constitutes a somewhat less stringent compliance standard; it thus allows a limited degree of deterioration in performance and generally assures a reasonable period of use before the device must be reconditioned.

Handbook 44 also specifies a set of special test tolerances, which apply to "special" tests. Special tests are tests that are made to develop the operating characteristics of the system and any special accessories or elements associated with it. Because they involve operating conditions that are not "normal" -- but which may and do occur in the field -- they permit a somewhat greater degree of inaccuracy than the values for maintenance and acceptance for "normal" tests.

The distinction between "normal" and "special" tests is set forth in two Notes included in the Vehicle-Tank Meters Code.

N.4. Testing Procedures.

N.4.1. Normal Tests. - The "normal" test of a measuring system shall be made at the maximum discharge rate that may be anticipated under the conditions of the installation. Any additional tests conducted at flow rates down to and including one-half of the sum of the maximum discharge flow rate and the rated minimum discharge flow rate shall be considered normal tests.
(Amended 1992)

N.4.2. Special Tests (Except Milk-Measuring Systems). - "Special" tests shall be made to develop the operating characteristics of a measuring system and any special elements and accessories attached to or associated with the device. Any test except as set forth in N.4.1. shall be considered a special test. Special tests of a measuring system shall be made as follows:

- (a) At a minimum discharge rate of 20 percent of the marked maximum discharge rate or at the minimum discharge rate marked on the device, whichever is less.
 - (b) To develop the operating characteristics of the measuring system during a split-compartment delivery.
- (Amended 1978)

Tolerance values for both normal and special tests are set forth in paragraph T.2 of the Vehicle-Tank Meters Code. Table 1, from paragraph T.2, sets forth tolerances for all vehicle-tank meters except milk, agri-chemical, and mass flow meters. (Tolerances for these meters are included in separate tables in T.2 in the Mass Flow Meters Code, which have not been reproduced here.)

As you can see, the value of the tolerance increases with the quantity indicated (i.e., with the size of the test draft). However, note that, expressed as a percentage of the indicated quantity, the tolerances actually decrease as the draft size increases. For example, the basic maintenance tolerance for a 100-gallon draft is 75 cu in, or 0.3246 percent, but the basic maintenance tolerance for a 200-gallon draft is 125 cu in, or

0.2705 percent. This reflects the characteristic described above, that the inaccuracy resulting from inertial factors at the beginning and the end of the draft is constant for any given size of draft, but represents a smaller proportion of the total delivery the larger the amount delivered.

Table 1. Tolerances for Vehicle-Tank Meters Except for Vehicle-Mounted Milk Meters, Agri-Chemical Meters, and Water Meters			
	Normal tests		Special tests
Indication	Maintenance tolerance	Acceptance tolerance	Maintenance and acceptance tolerance
(Gallons)	(Cubic inches)	(Cubic inches)	(Cubic inches)
50	50	25	50
Over 50	Add 1/2 cubic inch per indicated gallon over 50	Add 1/4 cubic inch per indicated gallon over 50	Add 1 cubic inch per indicated gallon over 50

Paragraph T.1 (not reproduced here) states that performance tolerances apply to errors of underregistration and overregistration.

- Underregistration is the indication of a smaller volume of product than has actually been delivered and generally favors the buyer. When the system is underregistering, the prover reading will indicate a positive (plus) error.
- Overregistration is the indication of a greater volume of product than has actually been delivered and generally favors the seller. When the system is overregistering, the prover reading will be a negative (minus) value.

You should record all applicable tolerances before beginning the Test. For a given metering system, you will need to determine one basic tolerance (either maintenance or acceptance) and the special tolerance that will apply.

4. Repeatability.

Repeatability refers to a device's capability to repeat its indications under reasonably similar conditions. In order to comply with Handbook 44, a device must be capable of repeating within prescribed tolerances its indications and recorded representations.

T.4. Repeatability. - When multiple tests are conducted at approximately the same flow rate and draft size, the range of the test results for the flow rate shall not exceed 40 percent absolute value of the maintenance tolerance and the results of each test shall be within the applicable tolerance. See also N.4.1.2.
(Added 1992) (Amended 2001)

When conducting multiple tests of a vehicle-tank metering system at approximately the same flow rate, the range of test results shall not exceed 40 percent of the absolute value of *maintenance* tolerance and the results of *each* test shall be within applicable tolerance.

Consider the example of two 100-gallon normal test drafts run at approximately the same flow rate. If maintenance tolerance applies, the tolerance for each individual draft is 50 cubic inches plus 1/2 cubic inch per indicated gallon over 50. Thus, the applicable, maintenance tolerance is:

$$50 \text{ cubic inches} + [1/2 \times 50] = 75 \text{ cubic inches}$$

As specified in paragraph T.1., the tolerances apply to both errors of underregistration and errors of overregistration. Therefore:

$$\begin{aligned} \text{maintenance tolerance} &= +/- 75 \text{ cubic inches} \\ \text{absolute value of maintenance tolerance} &= 75 \text{ cubic inches} \end{aligned}$$

The repeatability tolerance specified in paragraph T.4. is calculated as 40 percent of the absolute value of maintenance tolerance:

$$75 \text{ cubic inches} \times 0.40 = 30 \text{ cubic inches}$$

If the result of the first test is -40 cubic inches and the result of the second test is +50 cubic inches, each test result is within the plus or minus the applicable +/- 75 cubic inch maintenance tolerance permitted for individual test drafts. However, the results have a range of 90 cubic inches (-40 to +50 cubic inches) which exceeds the repeatability tolerance of 30 cubic inches.

5. Note totalizer reading.

As you know, totalizers are usually not considered to be primary indicating elements, and so are not subject to the specific requirements that apply, for example, to the register and ticket printer. However, they have an important function in the Test. At the conclusion of the Test, the inspector must record on the official report form the total quantity of product that has been delivered in the course of the examination. This is necessary so that the operator can reconcile inventory figures (the product used in the Test will have been returned to the possession of the operator, but will have been metered, and so will be included in the amount shown on the totalizer as delivered). Recording the totalizer reading at the beginning and the end of the Test provides this information without the time-consuming computation required to add the quantities registered for each separate test draft. You will simply subtract the beginning reading from the ending reading: the result will be the total quantity delivered in the course of the Examination.

As mentioned earlier, one additional set of determinations must be made before testing gravity-discharge systems:

6. Determine that a compartment or compartments have a sufficient amount of product to conduct "high head" and "low head" tests.

"Head" is a technical term for the height of the top surface of the liquid product contained in the vehicle tank above the delivery point (the point where product leaves the discharge nozzle). In a gravity-discharge system, the discharge rate developed at any given point during a delivery is directly proportional to the head. So when the tank is full, the system will deliver product at a higher discharge rate than when it is one-half full, and the discharge rate will be proportionally lower still when the tank is nearly empty. In order to develop the operating characteristics of the system over its range of flow rates, the normal test of a gravity-discharge system involves drafts at "full head" (with the tank full), at "medium head" (with tank about one-half full), and at "low head" (by definition, when the tank holds about one-and-one-half times the nominal capacity of the prover). If the tank has two compartments, one should be full at the beginning of

the Test and the other compartment empty. This will allow you to regulate the quantity of product contained in the first compartment for the medium head and low head tests by returning all or part of the first test draft to the empty compartment. This transferring process can be eliminated if the tank has three or more compartments, since one can be filled to full head, one to medium head, and one to low head in preparation for the Test. If the tank is not compartmented, some suitable receiving vessel will have to be provided in which to return all or part of the test draft after the full head and other tests. In any case, you should ascertain from the operator the capacity of the tank or tank compartments and the level to which they are filled prior to the start of the Test and record this data for future reference.

THE TEST

When you have completed all Pre-test Determinations, you are ready to begin the Test. Each of the separate tests mentioned above involves drawing one or more test drafts. Because several steps in the procedure are repeated for each draft, the EPO's list these repeated operations under the heading "Test Notes." The procedures described in the Test Notes are identical for gravity-discharge and power-operated systems. Before we turn to the tests themselves, let us look at these four basic and repeated procedures.

1. Wet prover. Allow the specified drain period each time the prover is emptied.

The procedure for wetting the prover, and the necessity for observing the specified drain period when emptying it, were described in the last chapter. It bears repeating, however, that this step is essential to assure accurate test results. If the drain period is exceeded by more than a few seconds, the prover should be re-wet.

2. Exercise care so that the product temperature is the same in the prover as in the meter.

As you know, most liquids expand when heated and contract when cooled. (Water and mixtures that are predominantly composed of water are exceptions to this general rule at temperatures close to their freezing point, since water reaches its highest density -- its greatest contraction -- at about 39.1 °F, and it will expand when heated or cooled from that temperature. However, water, and most products containing water, are generally maintained in vehicle tanks at temperatures that are considerably higher than 39.1 °F, and so will, for all practical purposes, follow the general rule). Depending on the physical properties of the test liquid, a relatively small increase in temperature can have an effect on the volume of a test draft that is significant for testing purposes. For example, the approximate coefficient of cubical expansion for gasoline is 0.0006 per °F. This means that one gallon of gasoline will expand by about 0.0006 gal for every degree Fahrenheit that its temperature is raised. If the temperature of a test draft of 100 gallons was to increase by as little as 2 °F over its temperature when it passed through the meter, the total effect would thus be:

gallons	x	coefficient of cubical expansion	x	temperature change (°F)	= volume change
100	x	.0006	x	2	= 0.12 gal = 27.72 cubic inches

This amount represents nearly three-quarters of the basic acceptance tolerance for a 100-gallon draft, and so could quite obviously lead to an erroneous determination.

The amount of temperature change that occurs under a given set of test conditions will depend upon a number of variables, including environmental factors (the difference between the temperature of the product in the system and the ambient temperature of the prover, the overall dimensions, design, and material of the

prover, the presence of wind, sun, precipitation, etc.), the size of the draft, and the elapsed time of the draft, measured from the beginning of flow from the discharge nozzle to the reading of the prover gauge. The total effect of the temperature change will depend upon the physical properties of the test liquid, primarily its coefficient of thermal expansion.

The number and variability of these factors make it practically impossible to predict the effect of temperature change under any particular set of test conditions. So the only way to determine whether the effect will be significant on test results is to record the temperature of the product at the meter and inside the prover at the time when a reading is taken. Most provers with calibrated capacities in excess of 200 gal are equipped with thermometer wells, which will facilitate determining the temperature of the product inside the prover. However, vehicle-tank meters are not required to be equipped with temperature sensing and indicating devices, so precise calculations based upon the temperature of the product as it is being measured are generally not possible.

If temperature measurements are available from both the meter and the prover, you should record them routinely. You should also ascertain the coefficient of expansion for the test liquid, either from the operator, or from appropriate liquid measurement tables. This will enable you to determine the effect of temperature change on the product by performing the calculation illustrated above. A similar computation must be made to adjust for the change in the capacity of the prover that will result from its being heated or cooled by the product to a temperature that differs from the one for which it was calibrated (usually 60 °F). The net result can then be subtracted from the prover reading to obtain the corrected error for the draft.

If you are not able to obtain accurate temperature readings of the product at the meter, the best you can do is to control, as far as possible, the factors that cause temperature change under test conditions. Avoid testing outdoors under extreme climatic conditions of any kind (temperature, wind, rain, etc.) and, if possible, avoid positioning the prover in full sun. The factor that is most controllable by the inspector is the elapsed time of the test. You should take prover readings as soon as possible after delivery is completed. If a test must be interrupted for an extended period of time and the results are close to the applicable tolerance (within 20%), it may be advisable to repeat the test. If these precautions are taken, it is unlikely that sufficient temperature change will occur during the course of the delivery to significantly affect test results.

3. Record totalizer indications before and after each draft to determine proper operation.

Since the totalizer will provide the basis for your calculation of the total quantity of product delivered during the Test, you should check its accuracy against the register for each test draft. The reason for repeating this check is that any discrepancy between the quantity indicated on the register and the quantity determined by subtracting the totalizer reading at the beginning of the draft from the ending reading may be attributable to a malfunction of the totalizer or of the register. If the discrepancy is consistent for each draft, either the totalizer or the register (or both) will require repair or recalibration. Inconsistency will usually indicate a mechanical problem in one element or the other, often the result of dirt or other foreign material in a gear train, or of excessive wear. Unless the totalizer is used as a primary indicating element, there is no tolerance for this check. Its results will, however, indicate whether the total delivery information you provide for the operator may be gathered using the totalizer, and the results may also be useful for diagnostic purposes.

4. After each test draft:

- a. print ticket if device is so equipped
- b. if computing type, check price computations on indicator and on recorded representations

- c. check all indicated and recorded values for proper comparability

If the system you are examining is equipped with a ticket printer, or if its register is of the computing type, all additional indications or recorded values must be checked for correctness.

The requirements relating to the information displayed on a printed ticket and the form in which this information is displayed were described in Chapter 5. To review:

- The ticket must show the total volume of the delivery in gallons and fractions of a gallon. If the system is of the computing type, the ticket must also show the unit price at which the system is set to compute and the computed total price.
- All recorded representations must be digital.
- All recorded representations must be readable.
- Recorded representations must agree with register indications exactly if the register is digital, or with the closest analog scale division if the register is analog.
- If the system is of the computing type, the money-value division must be one cent if the device is analog, or based upon a quantity-value division of 0.1 gallon or less if the device is digital.

In addition, the Vehicle-Tank Meters Code establishes a requirement for agreement between the computed price and the price computed mathematically (that is, by multiplying the indicated quantity by the unit price).

S.1.4.4. Money Values, Mathematical Agreement. - Any digital money-value indication and any recorded money value on a computing-type device shall be in mathematical agreement with its associated quantity indication or representation to within one cent of money value.

The allowance of one cent in the variation between the computed price and the price computed mathematically is intended to provide for the rounding of computed values to the nearest whole cent.

Again, the purpose of repeating these procedures after each test draft is to determine whether errors in indication or recording are consistent or inconsistent. Because consistent error generally indicates incorrect calibration and inconsistent error will indicate a mechanical (or electronic) malfunction, the results obtained may assist the operator and repairpersons to identify and isolate specific problems.

Tests to Develop the Operating Characteristics of the System

As explained in the introduction to this chapter, the characteristic accuracy curve of positive displacement meters necessitates performance tests over the range of discharge rates for which a particular system is designed and used.

The discharge rate of a gravity-discharge system varies with the level of liquid in the vehicle tank or tank compartment. (As you learned earlier, the discharge rate is proportional to the height of the liquid surface above the discharge point -- the head -- and not the weight of the product in the tank.) For example, a system

that delivers about 120 gallons per minute when the tank is full may deliver about 90 gallons per minute when the tank is approaching empty. The average discharge rate of any particular delivery will thus depend upon the level of product at the beginning of the delivery and the level of the product remaining at its conclusion. Because the average discharge rate of any delivery can be relatively high, low, or intermediate, and because the meter can be expected to perform differently at different flow rates, a gravity-discharge system is tested at high, medium, and low "head" (in fact, the relative levels specified apply more accurately to the tank level than to the head itself, which includes the vertical drop from the bottom of the tank to the discharge point).

The procedure for setting up these tests was described earlier under Pre-test Determinations. A single draft is drawn and the error recorded for each level specified. Timing the drafts will give you an approximate figure for the average rate of delivery. This should be done at least for the "high head" test, to determine whether the maximum rate developed by the system in use exceeds the recommended maximum rate marked on the device. As described in last chapter, Vehicle-Tank Meters Code, paragraph UR.1.1, requires that the actual rate not exceed the recommended rate.

Since all three drafts are drawn under conditions that pertain to normal commercial deliveries, they are designated "normal tests" for a gravity-discharge system, and the normal tolerance thus applies to the error observed.

In the case of a power-operated system, on the other hand, the discharge rate can be regulated, usually by the operator, using the discharge valve at the nozzle. Most power-operated systems are calibrated to measure deliveries most accurately at maximum flow, because it is at this rate that they are normally operated. However, because the system can be operated at lower rates and because, as you know, the rate can have a significant effect on performance, two test drafts are required.

The first is drawn at full flow (discharge nozzle wide open). This is the "normal test" of the system, and the basic tolerance applies to the results obtained. As for gravity-discharge systems, this delivery should be timed, to determine that the actual maximum discharge rate does not exceed the recommended rate.

The second draft is drawn at the system's recommended minimum rate (as marked on the meter), or at 20 percent of the maximum recommended rate, whichever is lower. Because the conditions under which this test is conducted are not "normal," it is designated a special test, and the special tolerance is applied to the results. This draft must be monitored with a watch or a stopwatch to assure that the correct rate is being maintained. Your instructor will demonstrate a technique for monitoring the slow flow delivery. Because this test can be expected to take about 5 times as long as the normal test, you must beware of the factor of time as it affects changes in volume due to temperature change and/or evaporation.

When performing repeatability tests great care must be taken to ensure that the conditions of the tests are identical. For example, the ability to halt the delivery when the register is at a scale division and the inspector's ability to read the prover and correct for any error, as described in Chapter 4, might have an effect on the degree of uncertainty in the reading officially recorded that is on the order of a single scale division.

As explained in the introduction, the difference between results for the maximum and minimum flow rates tested will provide a general indication of the condition of the meter. In general, the greater the difference in results the more likely that the meter is badly worn and in need of repair. The difference observed is likely to be less for gravity-discharge systems than for power-operated systems because even at "low head" the gravity-discharge system will still be operating at or above 50 percent of its maximum recommended discharge rate.

You should note also that the manner in which the tolerances are applied for these tests -- individually to the recorded error for each draft, rather than to the difference in recorded errors -- makes it possible that a system with a badly worn meter could receive approval under certain circumstances.

For example, consider the following results for tests conducted on a power-operated system employing a 100-gallon prover:

	<u>recorded error</u>
normal test	- 72 cu in
special slow flow test	+ 96 cu in

The applicable tolerances for these tests will be 75 cu in and 100 cu in, respectively. So the system is within tolerance for both tests and, assuming that it meets all other requirements, may be approved. However, the observed meter error for the two sets of tests suggests that the meter is badly worn, and probably is in need of reconditioning (note that an attempt to recalibrate the meter to reduce the observed error at either end of the flow range will in all probability push performance at the other end outside the tolerance).

The policies and procedures of some jurisdictions provide for rejecting a system found to be in this condition on the grounds that it does not meet the maintenance requirement set forth in the General Code (G-UR.4.1). Your instructor will explain your jurisdiction's policies in this regard to you. But whether the system is rejected or approved, you should be prepared to discuss your interpretation of test results with the operator at the conclusion of the test. If the device is permitted to remain in service, you should also make a note of its condition, and of the information provided to the operator.

The Split Compartment Test

This is a test of the capability of the air elimination component of the system to prevent air and vapor from entering the meter under the most demanding of circumstances -- when the fuel supply is exhausted and air floods the intake line rapidly. Under service conditions, this occurs when a tank compartment is emptied while a delivery is in progress. If the tank is multi-compartmented, and supply of the same product is available from another compartment, the operator closes off the manifold valve to the empty compartment and opens the valve to the new compartment without discontinuing the delivery (the pump generally remains engaged throughout this process, and the register is not reset). A similar situation occurs if the truck has only a single compartment or if supply of the product being delivered is not available from another compartment in a multi-compartmented tank. The difference is that under service conditions the operator of a single-compartment tank will terminate delivery when the supply has been exhausted, and the transaction will be completed on the basis of the quantity delivered to that point. Since accurate measurement under all of these circumstances depends upon the proper function of the air eliminator, the same "split compartment" test is applied to both single- and multi- compartmented vehicle tanks. However, the procedures are necessarily different, at least in part.

In either case, delivery to the prover is begun from a compartment containing less than one-half the nominal capacity of the prover at the system's full flow rate. When this supply of product is exhausted, the air eliminator should close the intake to the meter, preventing registration of air. The register should then stop and hold its current indication. If it does not, some air/vapor is leaking through the shut-off valve into the meter.

At this point, the test of a multi-compartmented tank will proceed as under normal service conditions: the pump will be left engaged while the manifold valve to the empty compartment is closed, and the valve to a compartment containing sufficient product to complete the draft is opened. The draft is then completed and the error recorded, as for the tests described above.

In the case of a single-compartment tank, additional product must be added to the tank to complete the test. This may be supplied from another truck or from a terminal. If no source of additional supply is available at the operator's location, you must arrange to perform at least this portion of the Test at a distribution site, or elsewhere. Sufficient product to complete the draft must be added with the pump disengaged if the system is power-operated, or with the control valve closed in the case of a gravity-discharge system. This will have the effect of interrupting the delivery. However, this is exactly what would happen under service conditions: the delivery would be discontinued and the single-compartment truck would be driven back to be refilled. In addition, if the delivery is not halted at this point, product splashing into the bottom of the empty tank and being drawn directly into the supply line will likely include far more entrained air than it would under normal conditions (since delivery would resume only after the tank was filled and the vehicle driven to another delivery location). For the same reason, the product should also be allowed to settle briefly in the tank, especially if it is susceptible to foaming, like no. 2 fuel oil. However, keeping in mind the possible effects of temperature change and evaporation on product already in the prover, this rest period should be kept to a minimum. Delivery is resumed, of course, without resetting the meter, and continued until the register indicates the nominal capacity of the prover. The error for the draft is then recorded from the prover in the usual way.

Ideally, of course, results for the split compartment test would be identical to those obtained from a normal test of the system, indicating that no air or vapor had been permitted to enter the meter when the supply of product was exhausted. However, it is recognized that even a system that is properly designed, installed, and maintained may permit a small amount of air/vapor to pass through the meter under these common, but extreme operating conditions. For this reason, the more liberal special tolerance applies to results of the split compartment test. This tolerance applies to the error observed for the test, not to the difference between the errors observed for the split compartment and the normal test(s). The reason for this is that the test error reflects what can be expected of a delivery made under service conditions, and this is the degree of error that would affect the final transaction between buyer and seller. However, it is important to remember that although its objective is to determine the capability of the air eliminator, the split compartment test is still a test of the entire metering system, of which the air eliminator is one functional component. For this reason, applying the tolerance in the prescribed manner could, under certain circumstances, permit a system with a badly functioning air eliminator to be approved.

For example, let us consider a maintenance test of a system using a 100-gallon prover. The basic tolerance will therefore be ± 75 cu in, and the special tolerance ± 100 cu in. Suppose that we record an error of $+70$ cu in for the normal test and an error of -95 cu in for the split compartment test. Technically, the system is within tolerance for both tests and, assuming that it meets all other requirements, should receive approval. However, all (or nearly all) of the difference of 165 cu in between results for the two tests may be attributable to malfunction of the air eliminator. If the system were adjusted without servicing the air eliminator, it could be expected to overregister considerably, especially under delivery conditions that approximate the test, but also, perhaps, under less severe normal operating conditions.

As a general rule, the greater the difference between the results obtained for the normal test and the split compartment test of a vehicle-tank metering system, the stronger the indication that the air eliminator is not functioning properly, and is in need of repair.

As in a situation where test results indicate a meter that is technically in compliance but which test results show to be badly worn, the policies and procedures of your jurisdiction might dictate rejecting a system found to be in this condition, on the grounds that it does not meet the maintenance requirement set forth in the General Code (G-UR.4.1). However, even if the system must be approved, you should inform the operator of this condition and make a written note of it, so that you or another inspector can follow up at the next scheduled examination.

Because any failure of the air eliminator should result in some degree of overregistration, you might expect any divergence between normal and split compartment test results to be in that direction. Although this is generally the case, you should be prepared to encounter the opposite situation, when test results indicate that the system is actually "giving" slightly more for the split compartment test. This should not be a cause of concern (unless the difference is extreme), and will, in fact, be an indication that the air eliminator is functioning excellently. The effect will be due to factors related to the test conditions, and especially to the fact that the meter will be started and stopped twice in the course of the test, rather than once, as in the normal test. As you will remember from our earlier discussion, inertial factors account for a certain amount (usually relatively small) of error at the beginning and end of each delivery -- generally in the direction of underregistration. The conditions of the split compartment test will double this effect.

RFI/EMI Test

All weighing and measuring devices that have electronic components are subject to the effects of radio frequency and electromagnetic interference (RFI/EMI). These two types of interference have different sources, but are basically the same in their nature and their effects.

The passage of electric current through a conductor creates a magnetic field around the conductor. If the direction, amplitude, or intensity of the current changes, the magnetic field surrounding the conductor changes in response. This changing magnetic field is then capable of inducing a current in another conductor located within the field (see Figure 6-3). The same effect can be achieved by changing the position of the conductor relative to a stationary magnetic field (this is the basic principle employed in electric power generation).

The circuitry of electronic devices consists of conductors that carry electrical signals. For example, you will recall from our discussion in Chapter 3 that in electronic registers, discrete signals generated by the transducer (pulser) driven by the revolving meter shaft are transmitted through wiring to the CPU, where they are interpreted. If this wiring, or the circuitry of the transducer or the CPU, were to be brought into contact with a changing electromagnetic field, extraneous current could be produced. This extraneous current could either interfere with the pulses generated by the transducer, rendering them unrecognizable as signals or, under certain conditions, it could produce additional pulses that might be interpreted as signals. In either case, the accuracy of the measuring device would obviously be impaired.

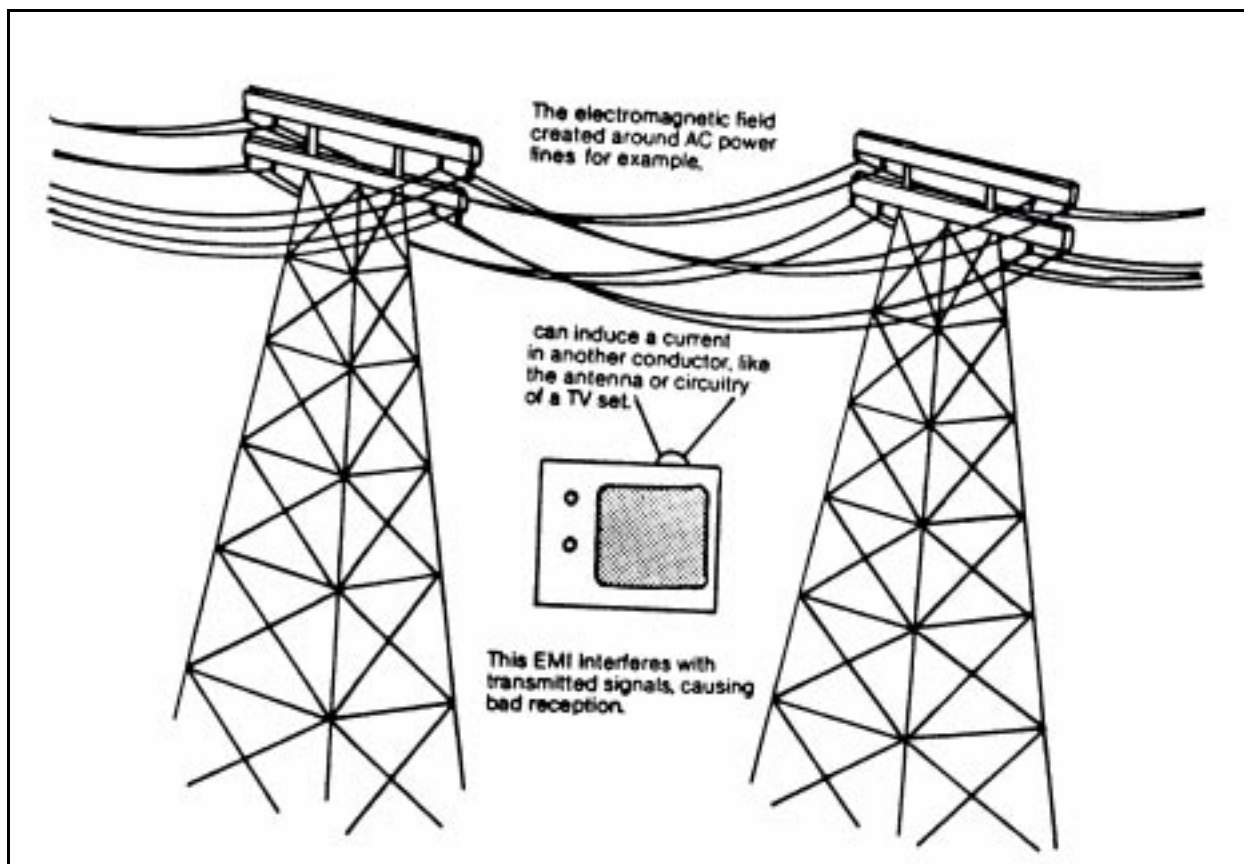


Figure 6-3. Electromagnetic Interference

Under normal operating conditions, vehicle-tank metering systems are exposed to electromagnetic fields produced from a variety of sources. Among these are:

- radio-frequency transmitters from nearby broadcast facilities and mobile transmitters, like CB and commercial band two-way radios and mobile phones (RFI)
- generators, including those driven by vehicle engines to provide a continuous power supply (EMI)
- electrical discharge ignition (spark plugs) (EMI)
- power supply lines (EMI)
- appliances that have electric motors, like air conditioners and refrigeration systems, compressors, etc. (EMI)

The components of electronic indicating and recording elements are designed in such a way as to be protected from interference from RFI and EMI under normal operating conditions. However, if these protections are defective or improperly installed, or if the equipment is located in a place where it is exposed to extraordinary amounts of RFI or EMI (for example, next to the transmitting facility of a commercial radio

or TV station), interference may occur. It is for this reason that electronic vehicle-tank metering systems should be tested for the effects of RFI/EMI.

The purpose of the testing procedure is not to determine the presence of RFI/EMI, but to determine whether the device is adequately protected from its effects, as required by Handbook 44. Several sections in the General Code include requirements that relate to RFI/EMI; these are listed below.

G-N.2. Testing with Nonassociated Equipment. - Tests to determine conditions, such as radio frequency interference (RFI), that may adversely affect the performance of a device shall be conducted with equipment and under conditions that are usual and customary with respect to the location and use of the device. (Added 1976)

G-UR.1.2. Environment. - Equipment shall be suitable for the environment in which it is used including but not limited to the effects of wind, weather, and RFI. (Added 1976)

G-UR.3.2. Associated and Nonassociated Equipment. - A device shall meet all performance requirements when associated or nonassociated equipment is operated in its usual and customary manner and location. (Added 1976)

G-UR.4.2. Abnormal Performance. - Unstable indications or other abnormal equipment performance observed during operation shall be corrected and, if necessary, brought to the attention of competent service personnel. (Added 1976)

Note that G-N.2. states that, when testing with nonassociated equipment, only "usual and ordinary" equipment may be used and that devices may be tested only under conditions that are usual and customary for their operation and service.

To conduct an RFI or EMI test, turn on the suspected source (when testing a vehicle-tank meter, you might, for example, turn on the vehicle's CB radio, if it is equipped with one) and then conduct a Normal Test as described above. Recorded results from this test should be compared to those obtained for the earlier Normal Test. If discrepancies are found, the susceptibility of the equipment to the RFI or EMI source can then be identified.

Test of the Preset Mechanism (if so equipped)

Systems used to make partial-load deliveries are often equipped with an automatic-stop mechanism, which will halt the delivery when a preset quantity of product has been dispensed. If the metering system you are examining does have a preset, its operation must be tested. This is accomplished by setting the preset for a pre-determined quantity and operating the system until the automatic mechanism trips the shutoff valve. The register indication (not the indication on the preset) is then compared to the pre-determined quantity. In accordance with the EPO's, the register must show that delivery was halted within one-half the minimum interval indicated on the register (usually 0.1 gal) for analog devices and within one increment for digital devices.

Because this is a test of the preset mechanism only, and not the measuring or indicating elements of the system, it is not necessary to deliver to the capacity of the prover. You should, however, preset the device for a delivery of at least 30 gallons and dispense at full flow. You should also observe the system closely as the delivery is approaching its conclusion. The shutoff should be smooth and the register should come to rest without jumping. An abrupt, jarring shutoff will indicate that the shutoff valve is not functioning properly (as described in Chapter 3). The resulting hydraulic shock transmitted back to the meter can cause accelerated wear and may cause erratic registration.

Antidrain Valve Test (power-operated systems only)

The final test prescribed in the EPO for power-operated systems is a test of the antidrain valve, which prevents the discharge hose in a power-operated system from being drained. As described in Chapter 3, the valve is calibrated to check flow when pump pressure is no longer present. The requirement for this test is included in the Vehicle-Tank Meters Code.

N.4.3. Antidrain Valve Test. - The effectiveness of the antidrain valve shall be tested after the pump pressure in the measuring system has been released and a valve between the supply tank and the discharge valve is closed.

At the conclusion of the preceding test draft, disengage the pump from the vehicle engine, raise a length of the discharge hose above the level of the meter, and attempt to deliver product into the plastic bucket. A small amount of product remaining in the discharge nozzle may be expected to issue from the nozzle. However, this flow should diminish and cease altogether after 30 seconds. If flow continues, or if you notice any change in the register indication, the antidrain valve is malfunctioning.

Additional Tests

The tests described above are those prescribed in the Examination Procedure Outlines for gravity-discharge and power-operated vehicle-tank metering systems. Your jurisdiction may require additional tests as part of an official field examination. Your instructor will describe any additional procedures to you.

SUMMARY

The purpose of the Test component of an official field examination is to determine whether the system being examined can perform within acceptable limits of inaccuracy (tolerances) under conditions that approximate, as nearly as possible, actual service conditions. The Test is comprised of several distinct procedures, each with specific objectives: some procedures are designed to develop the operating characteristics of the system, others to test the performance of specific elements. Before testing begins, a number of Pre-test Determinations must be performed to establish applicable tolerances and other test factors. Guidelines for Test procedures are provided in the EPO's. Interpretation of results obtained from various Test procedures can provide device operators, repairpersons, and weights and measures jurisdictions with important information regarding the current condition of the equipment tested.